17028



# Evaluation of Next Generation Military Vehicle Cooling Systems

Mary Goryca, US Army Tank Automotive Research, Development and Engineering Center

Neil Slyva, Flowmaster USA

# Report Documentation Page

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# Outline



- Thermal Challenges in a Military Environment
- Traditional vs. Alternative Approach
- Thermal Testing
- Thermal Tool
- Pilot Project – Applying the Simulation
- Results
- Next Steps

# Thermal Challenges



*Military needs differ from most commercial applications*

- Longer service life
- Shorter operational life
- Environmental extremes
- Worldwide operation
- Adverse operating conditions
- Both on- and off-road mission profiles
- Minimal maintenance during combat operation

# Thermal Challenges



*Cooling System Design Factors*

- Severe shock & vibration
- Long term storage
- Challenging longitudinal & lateral slopes
- Corrosive battlefield atmosphere & fording
- Ground-hop capability
- Airside clogging of heat exchangers
- Ambient temperature extremes & high altitudes

# Thermal Challenges



*Military vehicles are facing ever increasing challenges of meeting cooling system requirements*

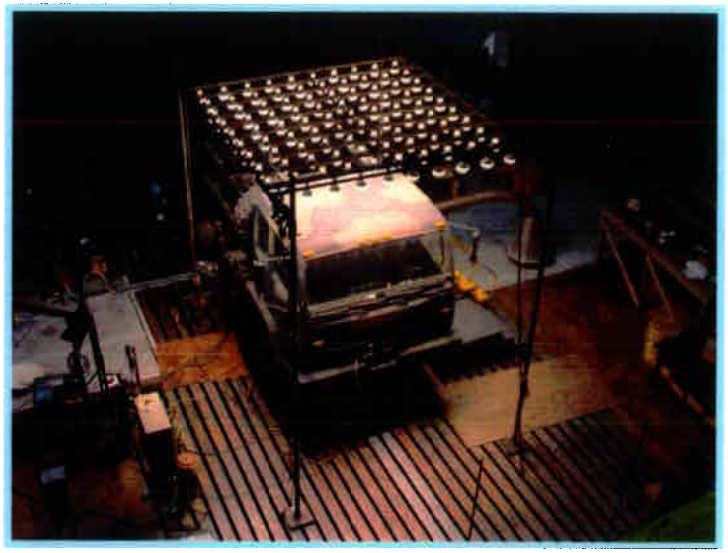
- Additional armor
- Power upgrades
- Extremely hot environments
- Heat loads associated with hybrids
- Adverse operating conditions

# Traditional Approach



*Meet thermal challenges through thermal testing*

- Optimize cooling system performance
- Select improved components – Radiator & Fan
- Conduct vehicle thermal testing
- Evaluate impact to cooling system



# Alternative Approach



*Share thermal challenge through an interactive technique*

- Connect vehicle level simulation with vehicle test
- Link 1D simulations to testing process
  - Evaluate multiple vehicle variants/configurations
  - Accomplish rapid optimization of thermal system
  - Identify best candidates to test
  - Achieve thermal goals

# Alternative Approach



*Benefits:*

- Minimize number of tests
- Maximize test results
- Save time
- Reduce cost
- Enhance cooling system performance capabilities

# Thermal Testing




## Objectives

Maintain critical temperatures within specified limits while operating at:

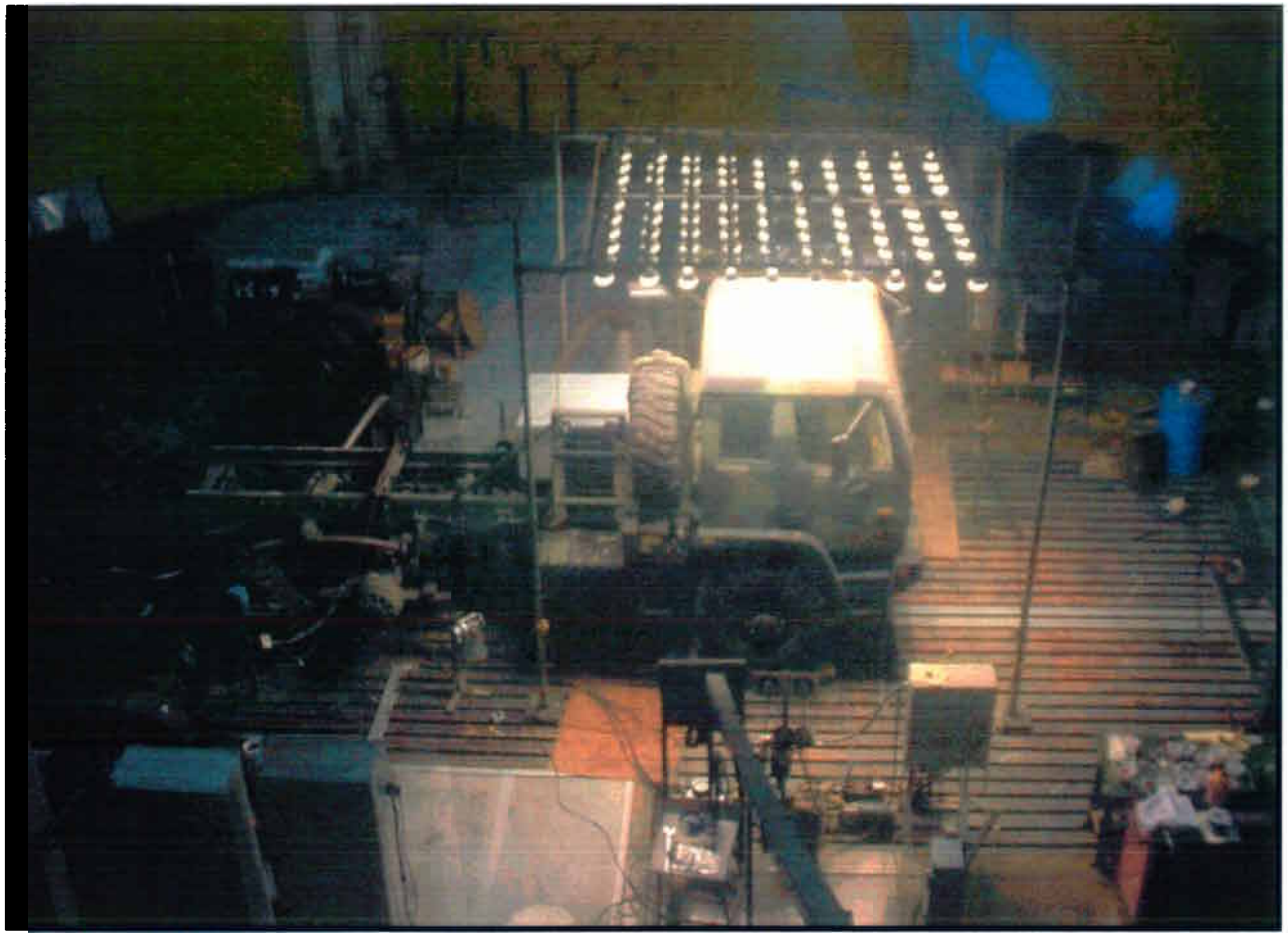
- Full power
- Full load
- Ambient 120ºF

## Specified Limits

- Engine Coolant 230ºF
- Engine Oil 275ºF
- Transmission Oil 300ºF

# Thermal Testing





## Test Conditions

- Full Power
- Full Load
- Ambient 120ºF
- 5 mph wind velocity
- Solar radiation

## Data Captured

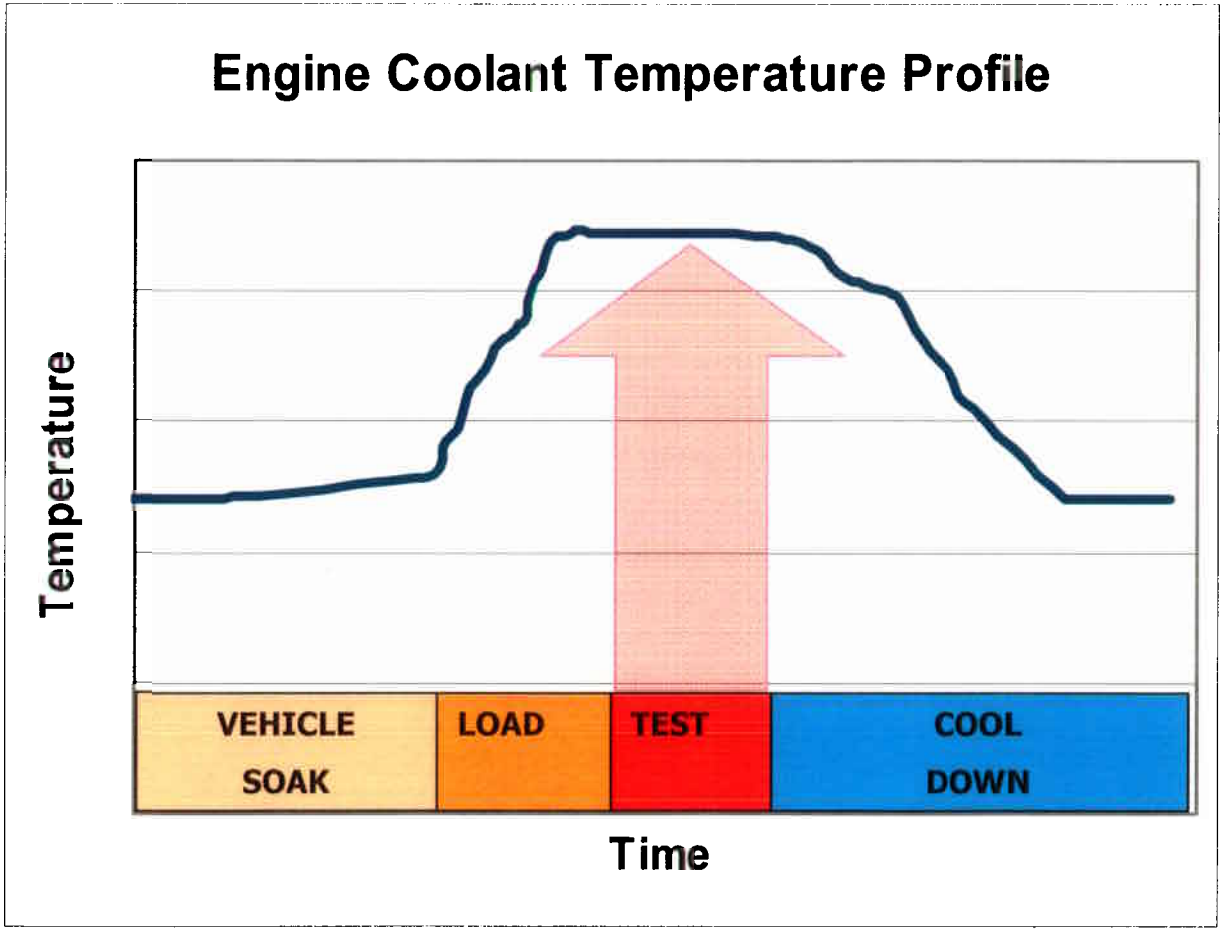
- Engine Coolant
- Engine Oil
- Transmission Oil

## Results

Determine if vehicle cooling system meets requirements in various configurations

# Thermal Testing





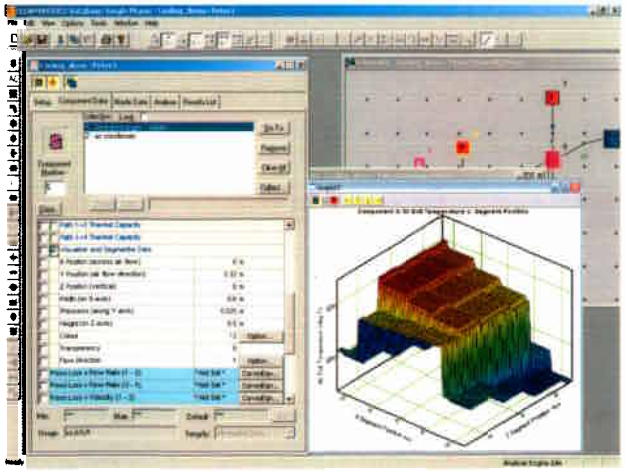

Thermal model simulates steady state conditions during cooling testing

# Thermal Tool - Technology



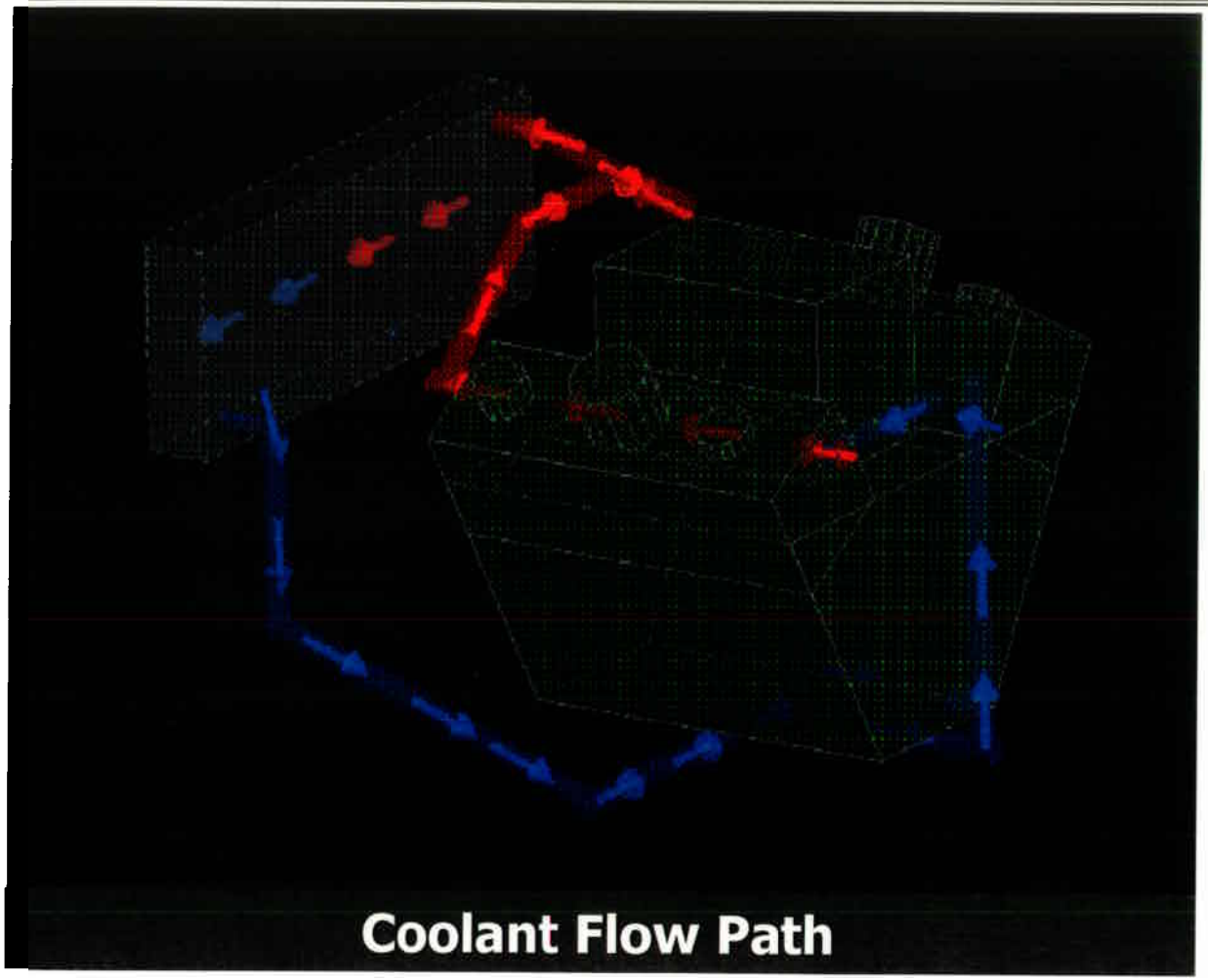
- Highly interactive tool with advanced features focusing on efficiency, accuracy, reliability and usability
- Facilitate connection between simulation and test process

Thermal Tool



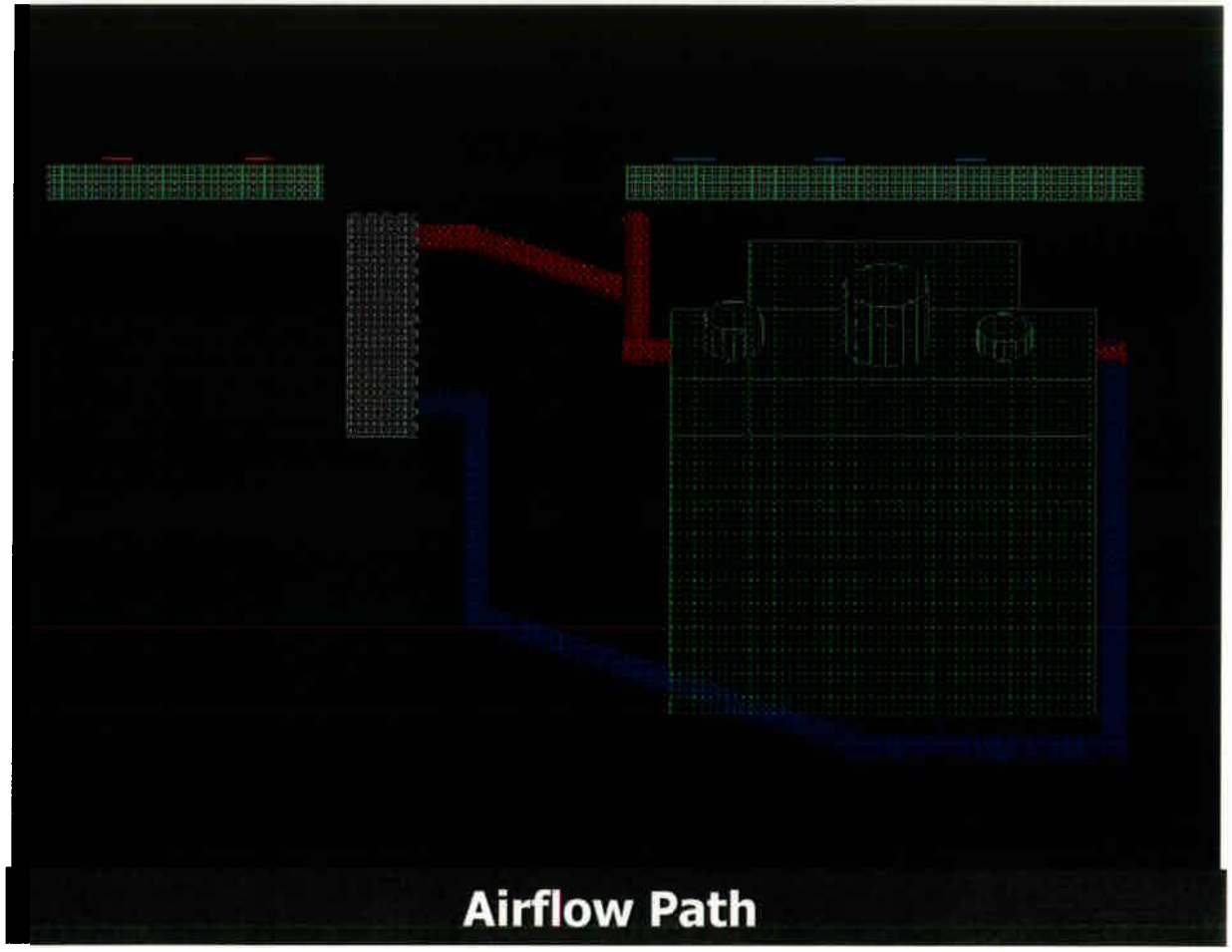
Thermal Test

# Thermal Tool - Function




- Model the coolant and airflow heat balance
- Predict critical temperatures
- Produce same results as test

# Thermal Tool - Function

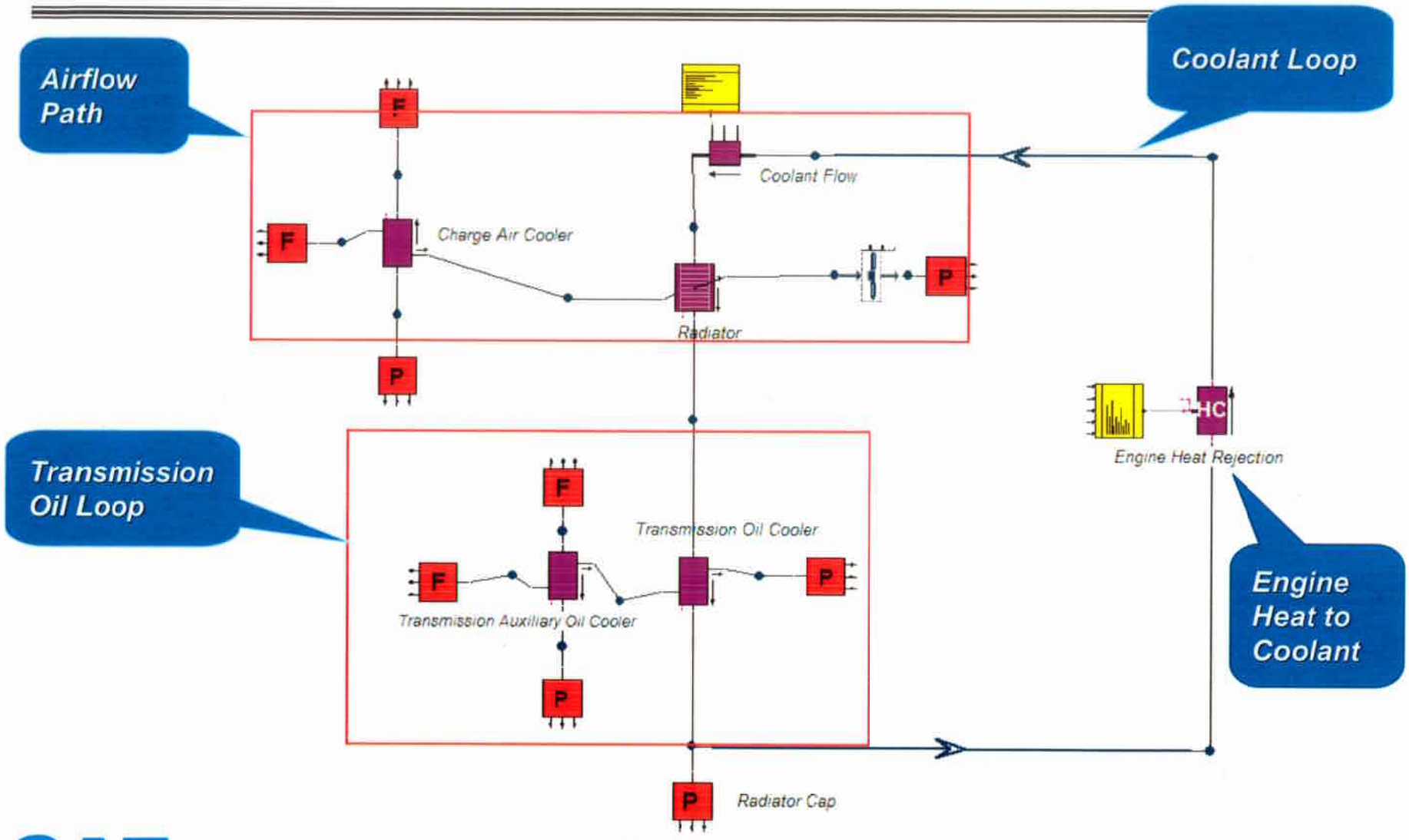


Airflow Path

- Model the coolant and airflow heat balance
- Predict critical temperatures
- Produce same results as test

# Thermal Tool – Function





# Pilot Project – Medium Tactical Vehicles



M1093 Cargo Truck

M1098 Wrecker

M1087 Expandable Van

M1090 Dump Truck

## Commonality

**Chassis**

**Drive Train**

## Differences

**Payloads**

**Mission Requirements**


Common Chassis

Material Handling Equipment

Load Handling System

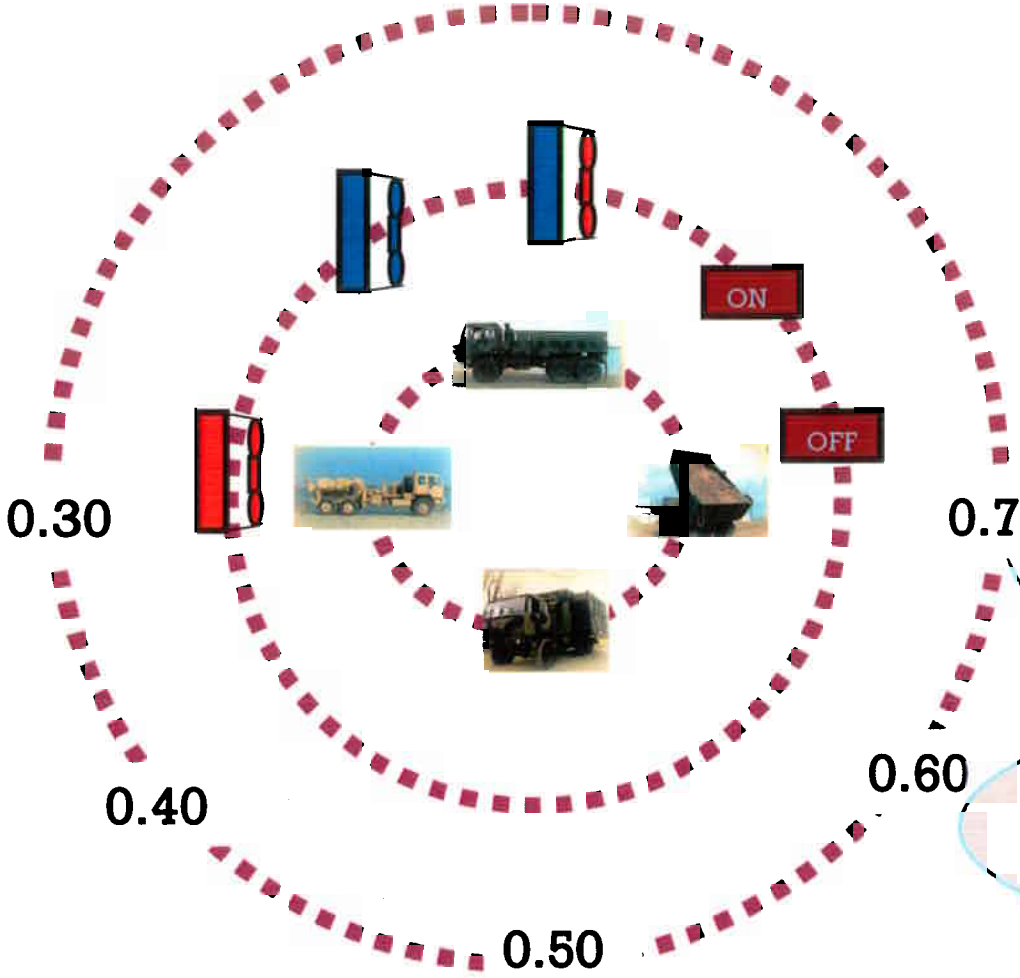
MTV

M1088A1 Tractor

SAE Unclassified

# Pilot Project – Test Matrix






Four Variants
Cargo
X-Van
Wrecker
Dump

Five Configurations:
Radiator/Fan (Base/Replacement)
Air Conditioning (on/off)

Five Tractive Effort/Weights
in high ambient temperatures

**Tradition approach only captured 40% of the desired data within this test matrix.**

# Pilot Project – Work Completed



*Major objectives have be accomplished*

- Captured test data from four MTV variants

M1093 Cargo Truck

M1087 Expandable Van

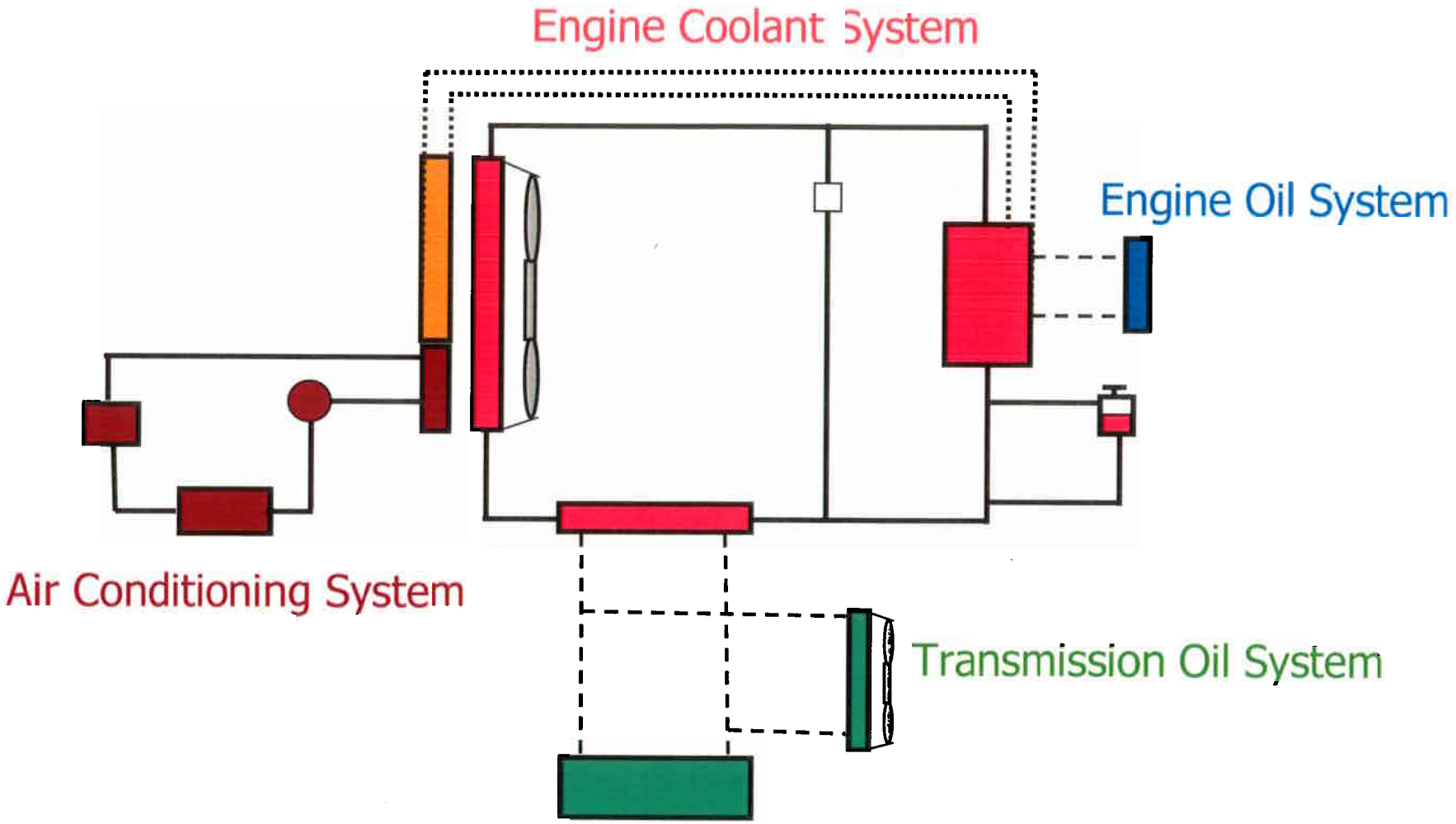
M1098 Wrecker

M1090 Dump Truck

- Developed several thermal models
- Validated models using actual test data

# Thermal Tool - Thermal Systems

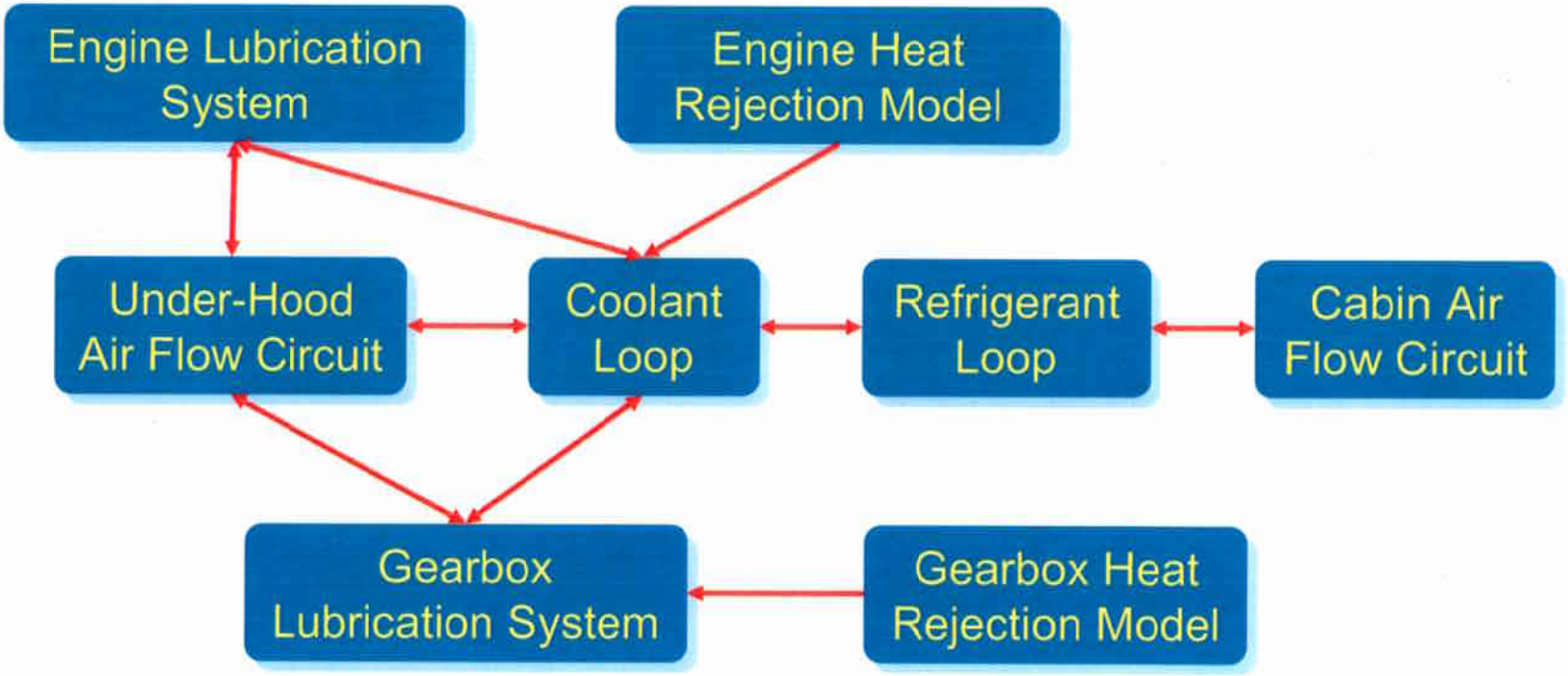




# Thermal Tool - Responsibilities

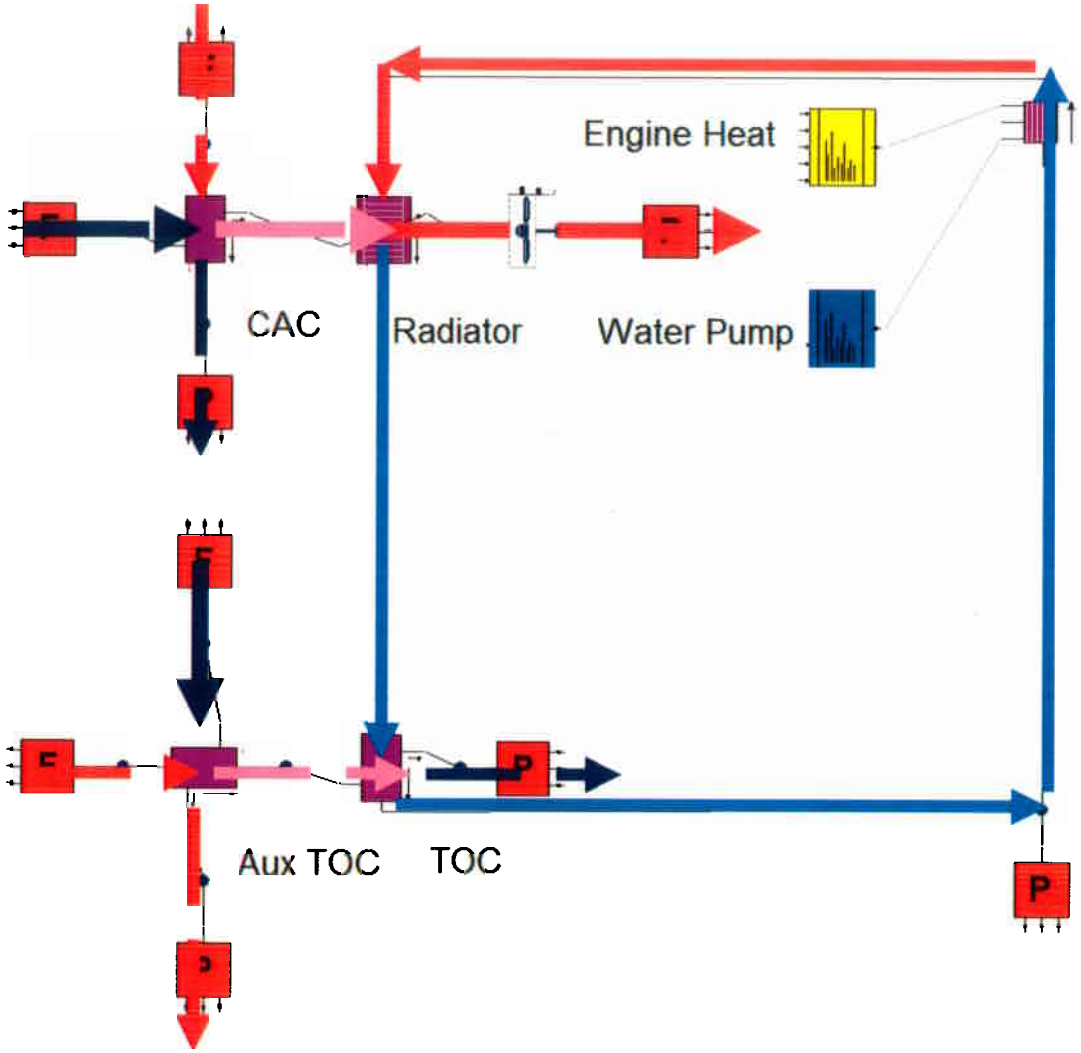


Thermal system interaction:



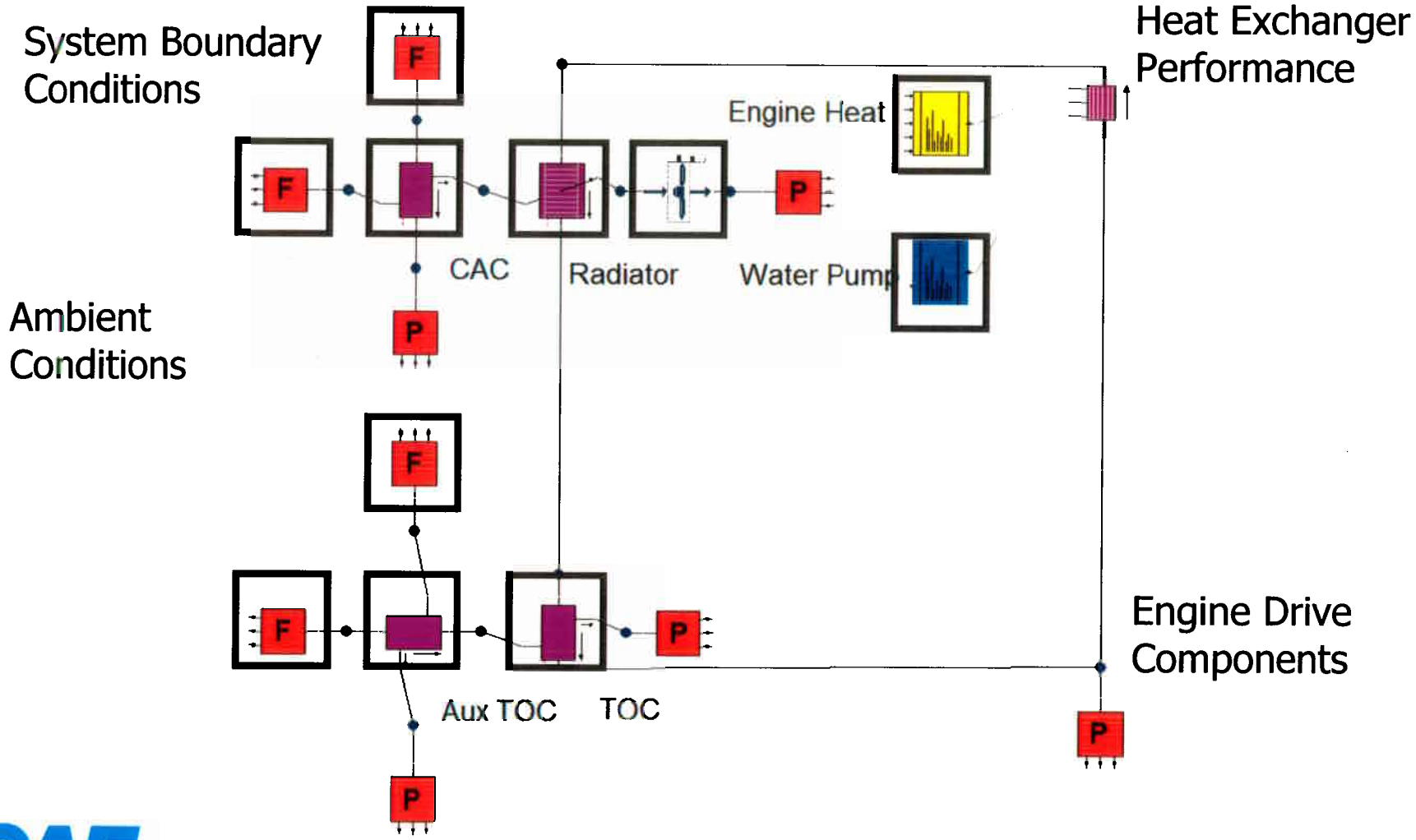
# Thermal Tool - 1D Model Set Up





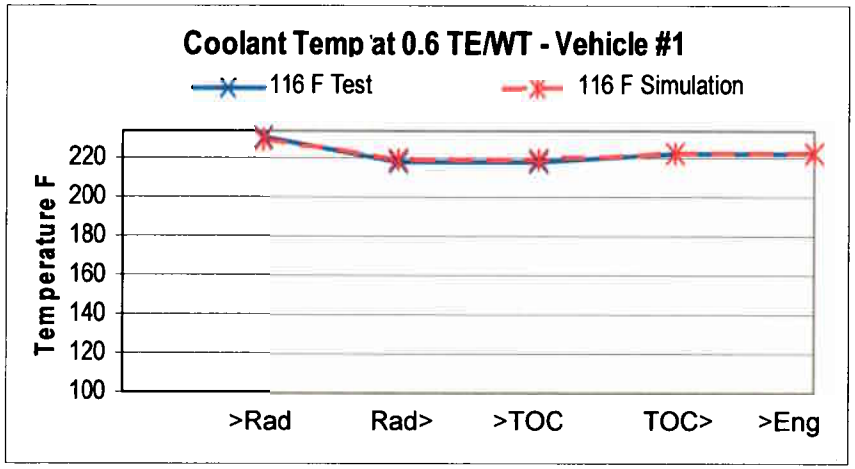
# Thermal Tool - 1D Model Set Up

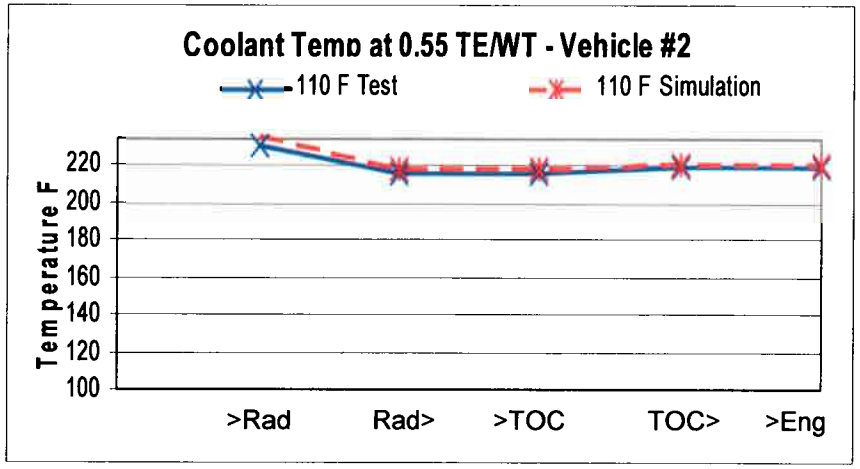


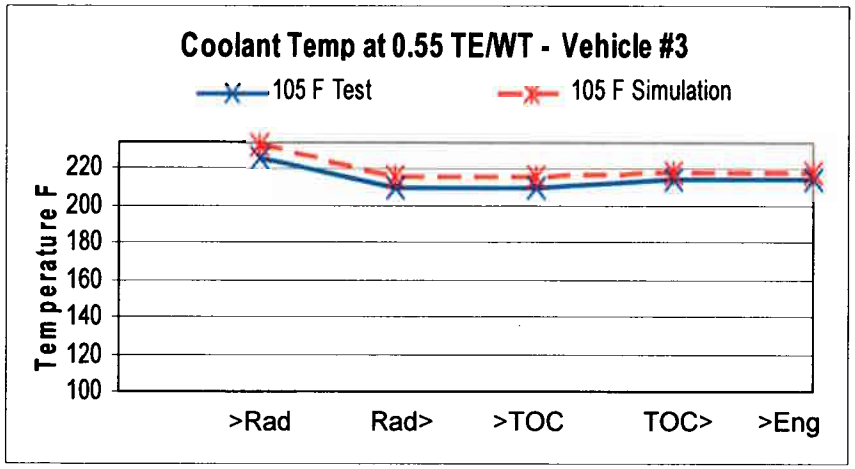


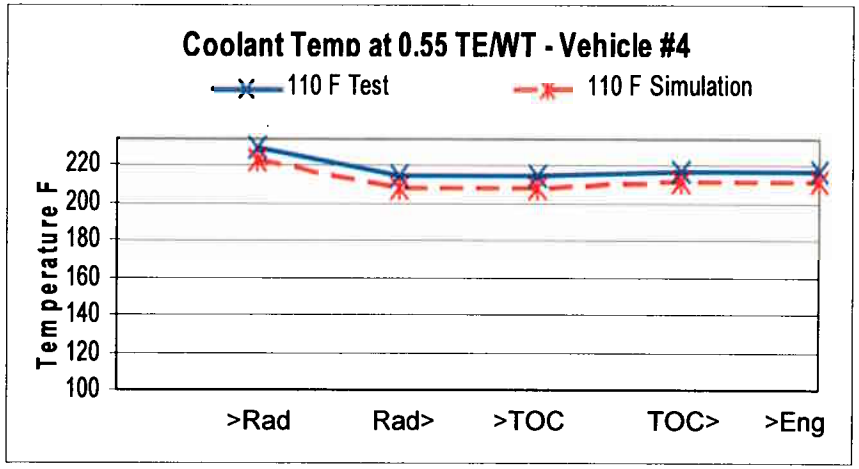
# Results – Coolant Temperature





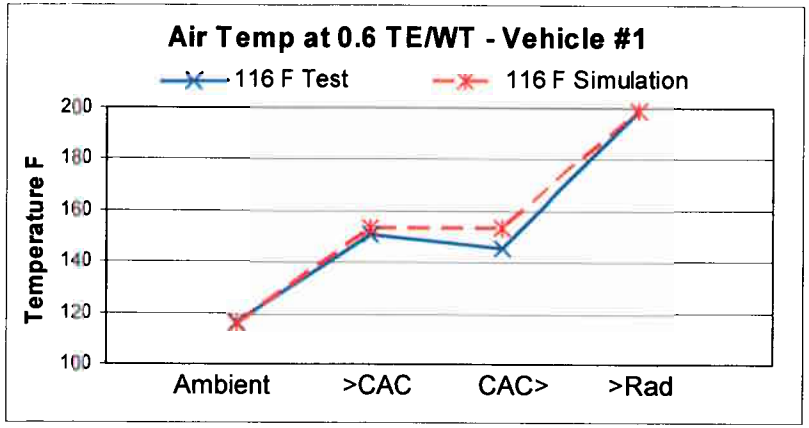



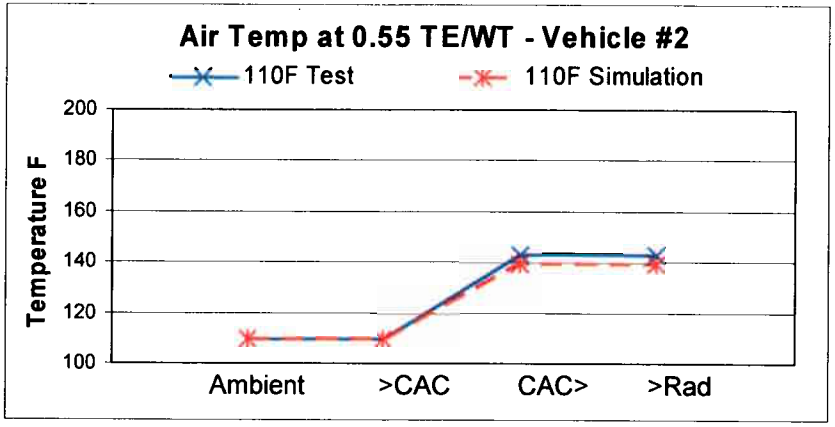



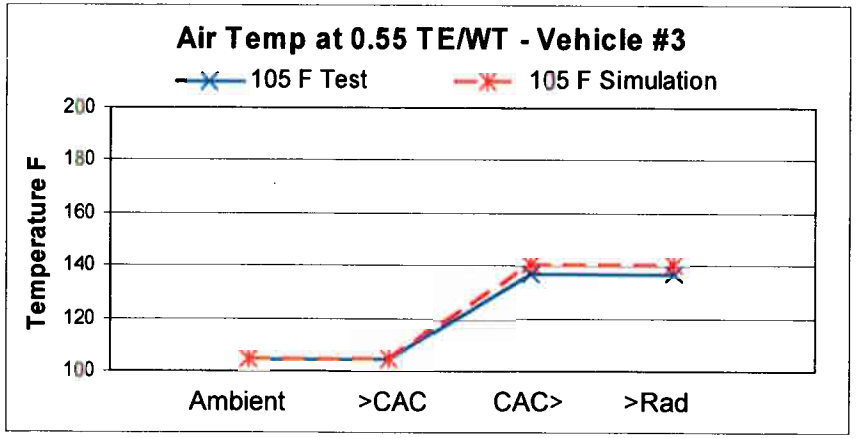



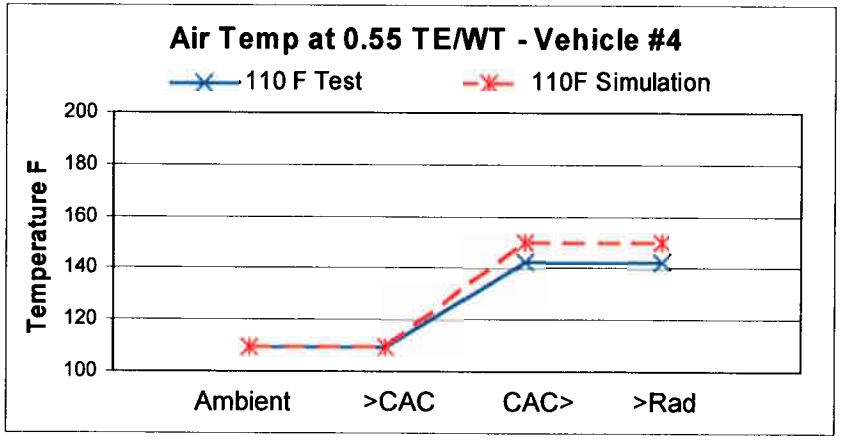
# Results – Air Temperature





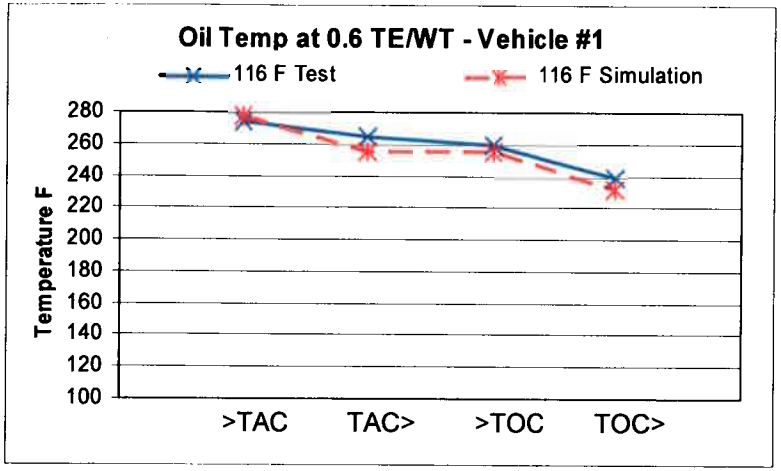



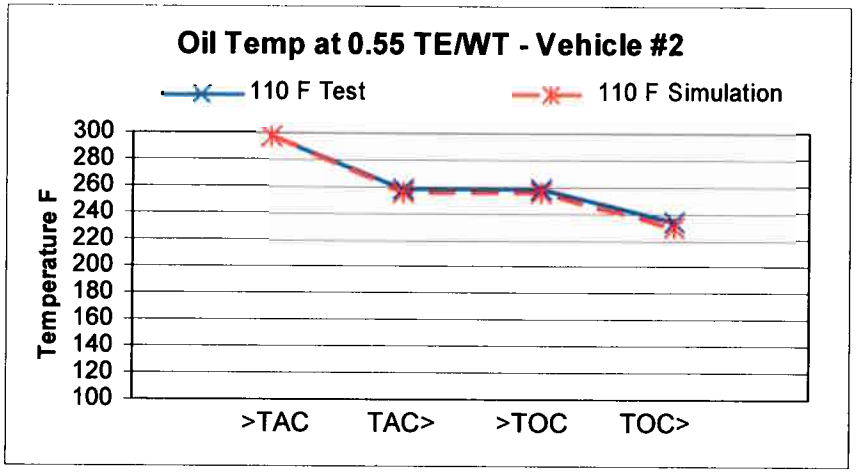



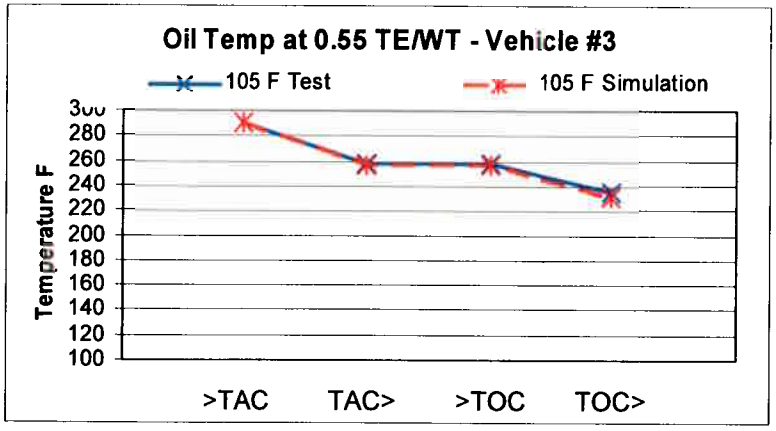



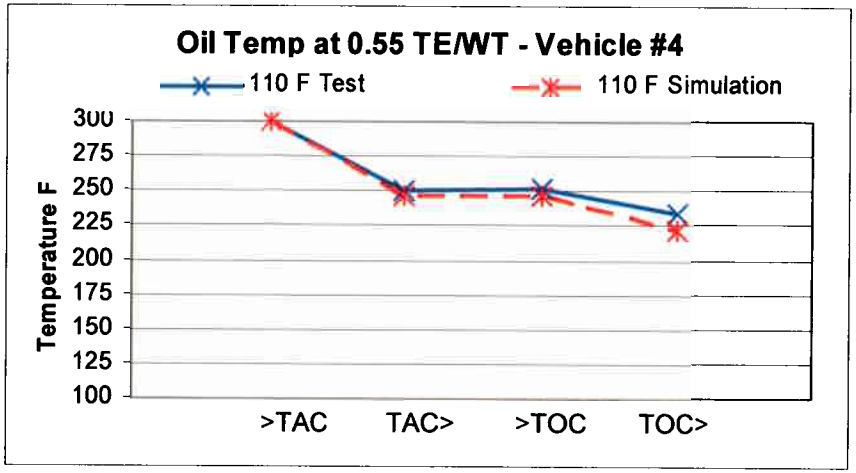
# Results – Transmission Oil Temperature





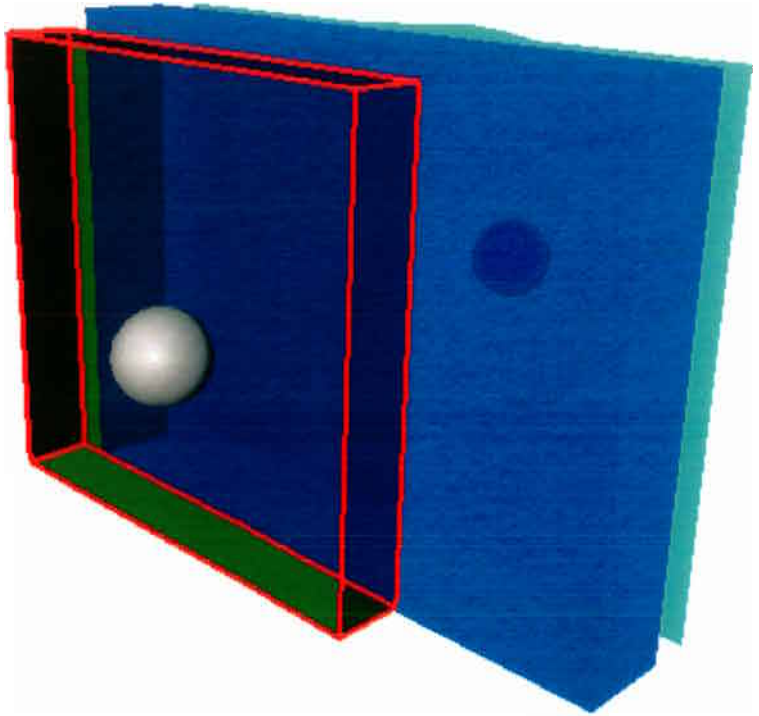



# Next Steps – Additional Variables



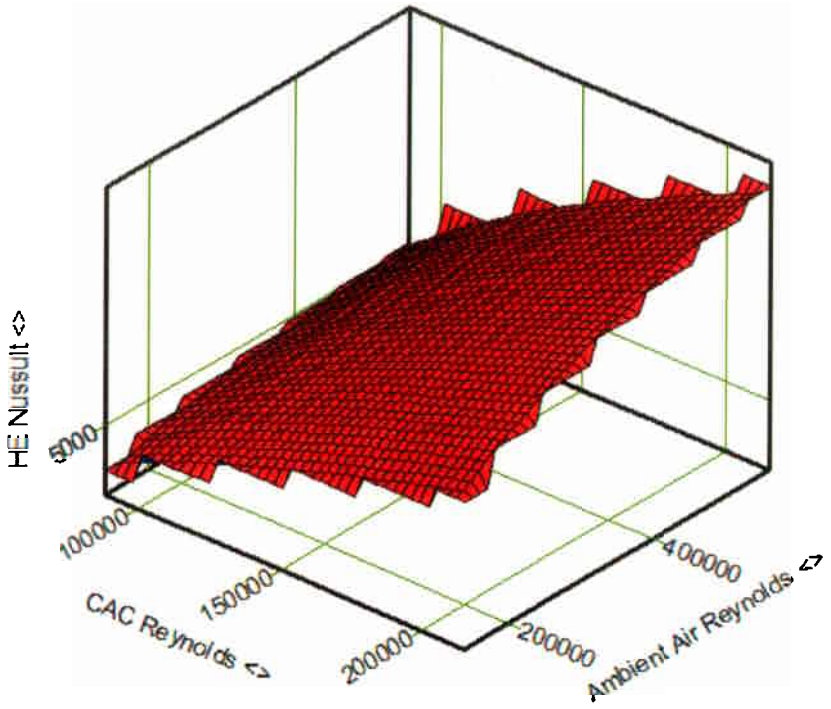
- Performance
  - Equal or better than existing exchanger under same operating conditions
- Variable Geometry
  - Height, width, and depth
- Variable Location



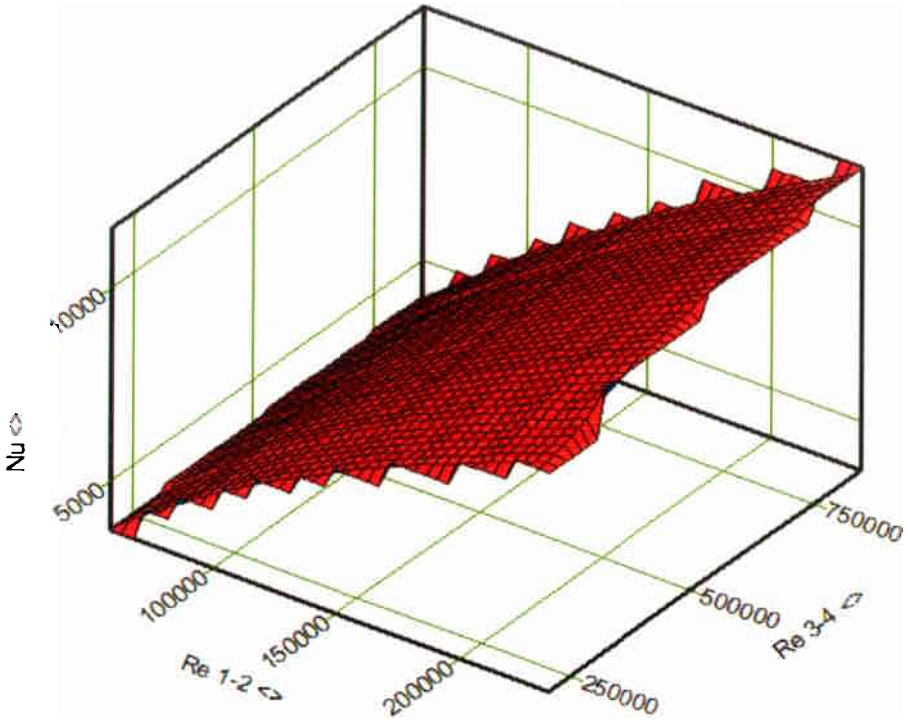
# Next Steps - Performance Input



Charge Air Cooler Nusselt Number vs. Re12 vs Re34 V3

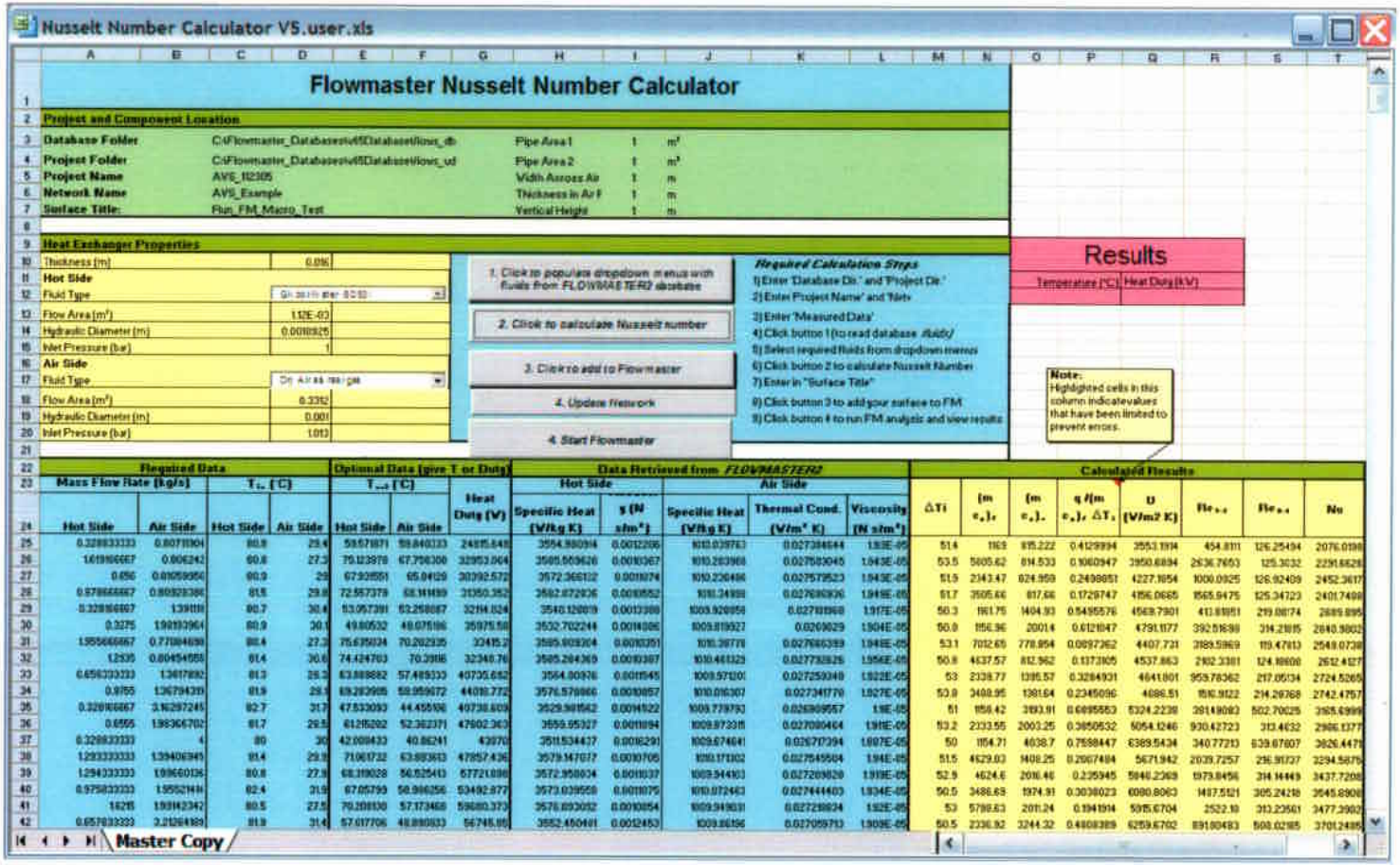



CAC Nu v Re1-2 v Re3-4



# Next Steps – Automated Approach





# Next Steps - Results

## Top Tank Temperatures

| | Vehicle A | Vehicle B | Vehicle C |
|---|---|---|---|
| **Heat Exchangers** | | | |
| **X** | 180 °F | 200 °F | 210 °F |
| **Y** | 180 °F | 200 °F | 210 °F |
| **Z** | 180 °F | 200 °F | 210 °F |

# Next Steps - Observations



- Simulation accurately represents cooling system performance
- Thermal simulation simplified complex interactions
- Initial validation process utilized:
  - Pre-processed component test data
  - Comprehensive vehicle test data
- Process enables rapid and accurate analysis
  - Heat exchanger options
  - Multiple vehicle variants
- Validating process for future heat exchanger evaluation

# Thanks for attending!

# Questions?

Mary Goryca, US Army Tank Automotive Research, Development and Engineering Center

Neil Slyva, Flowmaster USA